VI.

THE PALEOGEOGRAPHY OF THE NORTH-AMERICAN CONTINENT.

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The fitness of bringing before the American Geographical Society a theme which seems to belong rather to the province of the geologist will be admitted, if we consider that geography is in fact but a branch of that comprehensive study to which we may give the name of geology, and which, in its wider sense, includes the whole natural history of our earth from the earliest times to our own. To the geographer belongs the study of the present condition of the globe, its oceans and lands, its mountains and rivers, its soils and climates, and its plants and animals. Past and present astronomical and meteorological agencies, and the action of internal forces, have combined to produce the results which are the object of the geographer's study. The structure and arrangement of the materials of the earth's crust, its architecture, as it were, give rise to geognosy, while the theory of the origin and development of the globe constitutes geogeny. *Geogeny*, *geognosy*, and *geography* are thus three great divisions of the earth-science, or *geology*.

To the geological student the world of modern geographers is not the only one. In the distribution, arrangement, and varied nature of the rocky strata of the earth, and in the extinct races of plants and animals which they

envelop, he finds authentic evidence that each past geological period has had its own geographical history. Parts of the present ocean's bed cover the ruins of continents submerged, and our own continental areas included at times fresh-water lakes, seas with verdant islands, salt-water basins in the midst of a dry and desert land, or coastal regions swept by great marine currents, often charged with ice; and these varying conditions were in turn exchanged for "the stillness of the central sea." The record of animal and vegetable existence is traced backwards through all this varying succession until the dawn of plant-life is dimly seen in the oldest known of our rocky strata, those of the eozoic age. The student of organic fossils constructs from their history the sciences of *paleophytology* and *paleozoölogy*; and we may also, from the records of the attendant physical changes, construct what may be appropriately named *paleogeography*, or, the geographical history of these ancient geological periods.

This study is one which has often engaged the attention of geologists, and maps have been made to show the distribution of land and water on the European and North-American continents in various geological periods, based upon the distribution of the sedimentary rocks. Other principles may, however, serve to guide us to a further knowledge of these periods, of the rain-fall and evaporation over certain areas, of ocean-currents, and of the distribution of organic forms; principles which have not yet received all that attention which is their due, and which may be, to some extent, illustrated on the present occasion in a sketch of certain phases in the history of the North-American continent.

The period in which were deposited the various crystalline rocks of the Laurentides, the Adirondacks, and the Appalachians, offers in its greatly disturbed and contorted strata but very obscure data for its geological history. That the deposition of mechanical sediments went

on under conditions not altogether like those of later periods, but still so much resembling them as to admit of the existence of both vegetable and animal life, seems clear, and justifies for them the name of eozoic. That the long eozoic age was marked by several breaks is also evident from the fact that in these crystalline rocks have been included three or four distinct and unconformable series, if not many more, all of which are found developed alike in the Laurentian and the Appalachian regions. Of these series, however, over great areas, only the oldest and most resisting, the Laurentian, remains.

What Prof. Dana has called the azoic, but which may rather be called the eozoic, nucleus of the North-American continent includes portions of all of these; but, as defined by him, represents but a small portion of the land which in this part of the globe appeared above the ocean at the beginning of the paleozoic age; since besides the crystalline rocks of the Laurentides and the Adirondacks must be included the similar ones of the Appalachians, which now stretch from the Gulf of St. Lawrence nearly to that of Mexico, and in their present extent represent but a small portion of a great continent of whose former outlines we can form but an imperfect notion. Connected to the north-eastward with the Laurentide region, it must have extended far into the Atlantic, and formed the eastern limit of a great paleozoic basin, the western boundary of which was the Rocky Mountains. Within the basin were deposited the sedimentary formations of the New York system, including the Cambrian, Silurian, Devonian, and carboniferous rocks. The region in the vicinity of the Adirondacks, and to the west of them, was at the commencement of the paleozoic period a great plateau, which, at one time, was but partly submerged, and presented wide tidal flats, the sands of which are marked by ancient ripple-marks, wind-marks, and tracks of the animals belonging to the time of the Potsdam sandstone.

About this period, however, great thicknesses of sediments, differing widely in volume and in mineral character from those of the plateau, and in part made up of the ruins of the crystalline rocks of the eastern land, accumulated along the eastern shores of the basin. Meanwhile the plateau was, during a part of the time, above the level of the sea, and in parts cut off from the great oceanic circulation, and exposed to the influence of a very dry climate. The conditions which exist at the present day in the interior of our own and other continents, and give rise to deserts and salt lakes, were present at that early period over the great continental plateau already indicated. These conditions are dependent on mountain-barriers, causing the precipitation of a great part of their moisture from the currents of air which traverse them, so that the regions beyond, with a great rate of evaporation, have a scanty rain-fall, from which results the drying-up of saline waters and the generation of deposits of gypsum and rock-salt; in similar conditions, as I have endeavored to show, the magnesian limestones, which are the general associates of these, can alone be formed. The history of this great paleozoic basin affords ample evidence that between the limits of the Appalachians and the Mississippi considerable areas occupied by evaporating sea-basins existed at several periods in the paleozoic age; the first known example appearing in the subordinate Ottawa basin at the time of the deposition of the so-called calciferous sand-rock of the New York series, which is really a dolomite, inclosing in some parts gypsum, and impregnated with strong brines, which, from their great density, can be nothing else than ancient bitterns. To this local formation (followed by the Chazy) succeeded the wide-spread Trenton limestone, which, by its chemical characters, not less than its fauna, shows an open sea, and points to a movement of subsidence which disturbed the former levels, and made a partial break in the paleozoic series. This is

shown alike in its partial discordance with the underlying formations, the wide invasion by the Trenton sea of the adjacent land, and the noticeable break in the succession of organic life. The gradual filling-up of this sea by the influx of mechanical sediments, the ruins of older rocks, apparently from the north and east, and the accumulation from this source of the Utica, Hudson River, and Oneida formations, mark the close of this order of things, and serve to divide the rocks of the second fauna, or Upper Cambrian (Lower Silurian of Murchison), from the succeeding period, or Silurian proper (Upper Silurian of Murchison).

Following this disturbance there reappeared over large areas of the continental plateau conditions similar to those of the calciferous time, in which the marine fauna of the Clinton and Niagara formations became overlaid by the dolomites of the Salina group, which, with their interstratified gypsum and rock-salt, occurring over more than one area at this horizon, show that evaporation was carried to such an extent as to produce in Central New York and in Western Ontario great Dead Seas, whose bitter and saline waters were destitute of animal life. Over the deposits of this period, and beyond them, over the Upper Cambrian rocks, which formed the eastern shore of these inland Silurian seas, the waters of the ocean again flowed, and we find in the limestones of the Lower and Upper Helderberg divisions reproduced once more the conditions of the Trenton period. The movement which permitted this must have depressed considerably the mountains of the eastern shore, and for the first time in the paleozoic period permitted the ocean's waters to invade the Appalachian hill-country, in which, while no evidences of earlier paleozoic deposits are met with, strata with organic remains belonging to this period (the close of the Silurian and the commencement of the Erian or Devonian) are found. These deposits, often themselves much disturbed, are met with among the valleys of

Maine, New Hampshire, and Quebec, resting unconformably upon the older crystalline rocks, while they occupy similar positions upon the Upper Cambrian rocks of the Hudson and St. Lawrence valleys.

This submergence, which spread over wide areas the marine deposits of the Helderberg limestones, was, like the corresponding event of the Trenton period, followed by a silting-up of the sea, and the deposition of the argillaceous beds of the Hamilton formation then took place, followed by the great mass of sandstones and shales of the Erie division, the so-called Devonian or the Erian series of Dawson. These sediments, which came from the north-east, and thicken rapidly in that direction, marked the commencement of that great influx of material which continued into the carboniferous time and built up on a subsiding ocean-floor the great volume of later paleozoic sediments which is seen alike in Nova Scotia, and in New York and Pennsylvania. Made up of the ruins of older rocks, they show the results of the wasting and wearing-down of a great area of solid land of which the eozoic regions of New England and the British maritime provinces are the vestiges. That the shores of the sea in the corniferous period already bore a vegetable growth is shown by the remains of ferns found by Newberry in the marine limestones of that date in Ohio. A little later, in the time of the Hamilton formation in New York, there was an abundant growth of tree-ferns on its eastern shore, while further to the eastward, in Gaspé, the struggle between sea and land is shown in the presence of terrestrial vegetation in marine limestones probably of the Oriskany age.

As might be expected from the source of the land-making sediments, the whole of the Erian series in Gaspé is made up of them, to the exclusion of limestones, while to the westward the limestones of the lower part of that series, and later those of the carboniferous, are overlaid at both periods by these sediments, which, gradually

encroaching upon the sea, made a soil for the vegetation of the coal. That even at this period the meteorological conditions producing great dryness recurred at times over portions of this region, is shown by the gypsum and salt deposits of the carboniferous age, which are found not only in Pennsylvania and Michigan, but far eastward in Nova Scotia and New Brunswick. It is not necessary here to recall the story of the carboniferous period, with its great development of terrestrial vegetation over low marshy plains, in which appear, for the first time, the remains of terrestrial mammals and air-breathing mollusks.

The close of the paleozoic age in our eastern basin was succeeded by movements which raised above the sea the vast accumulations of sediments whose history we have sketched, and exposed them, contorted and dislocated, to that process of erosion which, operating down to our own time, has given its present relief to the continental area now occupying the place of the former paleozoic basin. Unlike the Old World, this eastern portion of the New has little to show for the long mesozoic period, during which so much of Western Europe was submerged. Along the Appalachian line, however, were formed in this age the remarkable sandstone deposits, of which those of the Connecticut and the Delaware are examples. These accumulations, many thousand feet in thickness, and made up in great part of the ruins of adjacent rocks, were formed in the lakes or estuaries, and exhibit in their character evidences of rapid deposition in subsiding basins, a process which was accompanied by great volcanic activity in and around these areas. Somewhat later the deposits of cretaceous and tertiary time were laid down beneath the waters of an ocean which stretched along the eastern, southern and western shores of the now elevated paleozoic area. Sediments of these periods, moreover, occur in Greenland, Spitzbergen, and elsewhere within the arctic circle, where strata, including coal and the remains of an abundant terrestrial flora, indicate as late

as the middle tertiary a climate in these far northern regions as mild as that now prevailing in Pennsylvania and Ohio, and a vegetation not dissimilar. Did time permit, we might trace, with Dr. Gray, the probable southward migration of this ancient northern flora into our Appalachian region. That similar climatic conditions had existed in the arctic zone at a much earlier time, is apparent from the remains of an abundant vegetation in the carboniferous period; nor is it certain that the present rigorous climate was ever known there until the miocene age was succeeded by that change which ushered in the present order of things, and, from the great part that ice played therein, is called the glacial period. To explain this changed condition of the arctic climate three classes of agencies have been invoked; viz., astronomical, chemico-physical, and geographical. While the former are supposed to have produced variations in the amount of heat received from the sun, I have shown that the chemical changes which have been effected in the atmosphere have served to render it less and less fitted to retain terrestrial and solar heat, and to protect the earth's surface from cooling by radiation, until a point was reached where we may suppose that changes in the areas of sea and land, and consequently in the distribution of warm equatorial currents, would suffice to produce over extreme northern and southern regions a temperature like that which in Greenland succeeded, after a considerable but unknown interval, to the mild climate of the miocene time. While these latter are doubtless true causes, adequate, either conjointly or separately, to produce a great refrigeration, it is by no means improbable that astronomical agencies may have coöperated. Even with the atmospheric conditions of earlier times, we may conceive glaciers to have existed in elevated regions and at high latitudes, and probable evidences of ice-action have been pointed out in the strata of paleozoic times.

The phenomena which in eastern North America and

elsewhere are referred to the glacial period are the erosion of valleys and lake-basins; the rounding, grooving, and polishing of rock-surfaces; the accumulation of great masses of unstratified clay, sand, and pebbles; the so-called boulder-drift, together with the formation of ridges, moraines, etc. To these succeeded the stratified marine clays and sands of what Dana has called the Champlain epoch, containing a fauna identical with that of our present northern seas. That these post-pliocene deposits show a temporary depression of the previously-uplifted continent far below its present level, and that ice in some form played an important part in the phenomena of the period, or of one immediately preceding, are points upon which all are agreed; but beyond this, wide divergences of opinion are met with, which concern primarily the time at which this submergence took place; and, secondarily, the mode in which the ice-action was exerted to produce the striation and the accumulations of unstratified material. On the one hand, it is asserted by a large school that these were produced when the region was at its present altitude, or even much higher above the level of the sea, and was exposed to a wide-spread glacier-action. But among this school opinion is again divided. Thus, Agassiz maintains the existence of one immense continental glacier or ice-cap extending over the arctic and a great part of the temperate zone, moving downward from the polar region, and of such immense height as to surround and overflow the summits of our highest hills, which he supposes may have required a vertical thickness of two or three miles of solid ice. This great glacier, having its under side filled with fragments of rock, is conceived to have acted like a rasp, cutting, grinding, and shaping the underlying rocky surface; and, when the period of the gradual melting came, to have left behind it the glacial drift which we now discover. Dana, on the other hand, while maintaining that these phenomena are due to terrestrial glacial action, regards the motion of a central

or common glacial source, or, in other words, a universal glacier, as unfounded, but supposes, nevertheless, the existence of distinct glaciers of enormous magnitude. Such a one, according to him, had its origin along the watershed between the St. Lawrence and Hudson's Bay; but, recognizing the necessity of an elevated source to give motion to the glacier, he supposes that this region, which is not more than 1,500 feet above the sea, was then raised many thousand feet above its present level, forming a mountain-plateau from which an immense glacier spread south-eastward to the ocean, filling the St. Lawrence valley, and covering, with its icy mantle, both the Green Mountains and the White Mountains, precisely like the continental ice-cap of Agassiz. The movement of such a glacier, however it may serve to explain the south-eastward striation of the Ottawa valley and of New England, leaves unaccounted for the not less distinct evidences of glacial action in a transverse direction, which are seen from Labrador up the St. Lawrence valley, as far as Lake Erie. These evidences consist alike in the striation everywhere visible, and in the forms of isolated hills of eruptive rocks, which, rising from the champaign country in the vicinity of Montreal, have bold and rounded fronts on their north-east sides, while their ruins form a talus to the south-west, and have even been transported long distances in this direction. All of these facts combine to show a long-continued eroding action from the north-east. Prof. Dana would explain this by a supposed south-westward flow of the lower part of the great glacier in this direction, along the St. Lawrence valley, while its upper portion was moving in a transverse course, across the mountain-ranges of the Appalachians, towards the sea. But this, even if we admit its adequacy to explain the phenomena of the St. Lawrence valley, leaves unaccounted for the extension of the same south-western striation around the basins of the great lakes, as far as Michigan and Superior, to explain which would

require the creation of another great glacier in the northern regions.

In both of the above theories of glacial action, a great depression of the surface is supposed to have succeeded the glacial period, effacing, in the one case, the great mountain-plateau to the northward, and submerging the glaciated region so as to permit the deposition above its surface of the stratified clays and sands which so often overlie the boulder-drift, from the rearrangement of which they appear to have been, in part, derived.

Besides these theories, which seek to explain the various glacial phenomena by the action of ice upon solid land, there is a third view, which, while maintaining the intervention of local glaciers, supposes that by far the greater part of the results which we have described was produced by sea-borne ice, during a period of submergence. This earlier view, which has lately been ably advocated by Dawson, endeavors to explain the phenomena in question by causes now in operation, rather than by supposing a condition of things which it is at once difficult to conceive and to explain, and is thus more in harmony with the principles of modern geological science. It maintains that at the beginning of the glacial time, whose record is written in such marked lines over the surface of north-eastern America, the region was already under water, and was slowly rising, though with minor oscillations of level, from the ocean, the more western portions first. Along the eastern border of the land, over its still submerged plains, and through its valleys, then flowed the arctic current, as it now does along the coast of Labrador and the shores of Newfoundland, bearing great quantities of floating ice, by the combined action of which, with the current, the rocky strata were eroded, and the valleys and lake-basins excavated. At an early period in this order of things, the great arctic stream, pursuing, in obedience to the force impressed upon it by the earth's rotation, a south-western course, passed over the region of the

lakes, and excavated the basins of Superior, Michigan, Huron, and Erie; while at a later time, diverted further eastward by the emergence of the Laurentides, it would pass along the present St. Lawrence valley, and thence south-westward to that of the Mississippi. To quote, in this connection, the language of Dawson, "The prominent south-western striation and the cutting of the upper lakes demand an outlet to the west for the arctic current. But both during depression and elevation of the land, there must have been a time when this outlet was obstructed, and when the lower levels of New York, New England, and Canada were still under water. Then the valley of the Ottawa, that of the Mohawk, and the low countries between lakes Ontario and Huron, and the valleys of Lake Champlain and the Connecticut, would be straits or arms of the sea, and the current, obstructed in its direct flow, would set principally among these, and act on the rocks in north and south, and north-west and south-west, direction. To this portion of the process I would attribute the north-west and south-west striation."

As the process of elevation proceeded, and the northern current found its passage to the sea by channels further and further east, the conditions became such as to permit the deposition, from seas comparatively undisturbed, of the stratified clays and sands which, in many cases, rest directly on the boulder-clay. Such beds, with marine fossils, are found in the St. Lawrence valley, at heights nearly 500 feet above the sea, and others, though without fossil remains, at much higher levels. Portions of floating ice, however, still dropped, from time to time, the rock-masses with which they were freighted, in the midst of these stratified clays; nor are there wanting evidences, in the Lower St. Lawrence, that a second invasion of icebergs may have given rise to a new accumulation of boulder-drift, after the deposition of the stratified clays, which there overlie, at Trois Pistoles, a still older deposit of the same kind, as noticed by Dawson. Such

a result might readily follow from a small local and temporary depression of level during the general elevation.

That some oscillations of the kind took place during this period may be inferred from certain facts in the history of the great lakes. The basins of these, according to Dr. Newberry, are so connected with each other and with the sea, by channels now filled with drift-deposits, that were these removed and the continent slightly elevated, the waters of the great lakes would be discharged through each other into the ocean, by the valleys of the Hudson and the Mississippi. The lake-basins of Michigan, Huron, St. Clair, and Erie, in fact, occupy a great depression, which was first excavated in the nearly horizontal paleozoic strata, and then filled up with stratified clays, in which the present basins were subsequently fashioned, so that from alternations of level the process of lake-erosion has been repeated over this region.

I have elsewhere pointed out that the base of these clays, beneath the south-western part of Lake Erie, of Lake St. Clair, and in much of the adjoining country, is far below the bottom of these lakes; so that it would seem that these present lake-basins have been excavated from the post-pliocene clays, which, in this region, fill a great ancient basin previously hollowed out of the paleozoic rocks, and including in its area the south-west part of the peninsula of Ontario.

The valleys of the hills and the shores of the islands, which then rose above an icy sea, would be filled with local glaciers, of which the marks still remain, which gave their tribute to the northern current, already charged, as now, with immense icebergs from the polar region, and these in great part submerged and half-stranded masses, urged by wind and tide, would plough and furrow the bottom, there piling up the unstratified heaps of boulder-drift, to which the earth and rocks, borne by the melting

ice, would contribute. It is a point of great significance, insisted upon by Dawson, that this glacial drift throughout the St. Lawrence valley often contains marine shells, and that the included masses of rock are frequently incrusted with barnacles and with polyzoa, showing that these materials must have been gathered not from the surface of a long-emerged continent, but from the bottom of the sea.

I have thus endeavored to set forth briefly the very different views which have been advocated in explanation of the phenomena of the glacial period in the history of our continent. These, according to the views of the land glacialists, were limited to a definite epoch, and operated simultaneously over a vast area, which, according to one hypothesis, was not less than an entire hemisphere. Those, on the other hand, who restrict the action of land-ice to local glaciers, and call in the aid of floating ice and the polar current, maintain that the process of glaciation is one limited rather by place than by time. Ever since the conditions of the earth have been such as to give rise to the formation of polar ice, the shores and the shallow seas, to which the arctic current flowing southward had borne it, must have been subjected to glacial action such as we have endeavored to describe. From the days in which the glaciation of our valleys was effected the process has not ceased, but has been transferred to other regions; and we conceive that the banks of Newfoundland, if now raised above the ocean's level, would present striations and glacial drift, which, but for the presence of remains showing its formation to belong to the historic period, would be indistinguishable from the ancient boulder-clays of the St. Lawrence valley.

The attempt which I have made, to-night, to set before the Geographical Society some phases in the physical geography of a portion of our continent, from paleozoic times downward, might be made more complete by trac-

ing the development and spread of animal and vegetable life over the upraised continent. The migrations of the present flora, especially, present many questions of great interest alike to the botanist and the geologist, but the adequate discussion of this question, even did time permit it, is one beyond my powers.

The view which I have announced above, that *the crystalline rocks of the Appalachians represent but a small portion of a great continent*, of whose form and outlines we can form but an imperfect notion, but which formed *the eastern limit of the great paleozoic basin*, is not a new one. So long ago as 1842, H. D. Rogers concluded that the sediments of the paleozoic age in the Appalachian region must have come from a continent, which, however, he placed to the south-eastward. Hall, in the introduction to the third volume of his Paleontology, has well shown the distribution of our carboniferous and still older paleozoic sediments, and their rapid increase in volume and in coarseness towards the north-east; and in my review of this work, in 1861, these sediments were spoken of as "evidently derived from a wasting continent," Hall, himself, having said, "We may have had a coast-line nearly parallel to and coextensive with the Appalachian chain." I have, in the present lecture, insisted still farther upon this view, and advanced, in favor of an elevated eastern continental area, an argument adduced from the climatic conditions which, as I have long since shown, must, throughout the paleozoic times, have prevailed at intervals in the basin to the westward. It was not until this address had been delivered and written out, as above, that I received the American Journal of Science for December, 1872, in which Prof. Joseph Le Conte announces, in language almost identical with my own, that the eastern part of the basin received its sediments "especially from a continental mass to the eastward." He admits that the gneissic region of the Atlantic slope of the Appalachians is Laurentian; but I

had already, in 1870, asserted the eozoic, and, in part, the Laurentian age of these rocks, hitherto regarded, in great part, as altered paleozoic strata. While it is gratifying to find my views on these points (and, in fact, my entire scheme for "reconstructing the whole foundation of theoretic geology on the basis of a solid earth") adopted by Prof. Le Conte, I deem it but right to call attention to the priority of my own conclusions.